Construction Engineering Technology
Program Assessment Framework

Abstract

With the ultimate goal of engineering programs to improve student learning, this paper presents the assessment framework developed, adopted, and implemented by the Construction Engineering Technology (CET) program at California State Polytechnic University, Pomona. The framework is set up to measure the attainment of both the Program Educational Objectives (PEOs) and Students Outcomes (SOs), as required by the Accreditation Board for Engineering and Technology (ABET). The assessment of the PEOs was conducted through indirect measures including surveys to alumni and industry advisory council. The assessment of SOs was conducted on a six-year cycle, in which both direct and indirect measures were used by the CET program. Direct measures included Performance Indicators (PIs) that are drawn from both the senior project and the coursework. Indirect measures included senior exit surveys, alumni surveys, and industry advisory council surveys. The framework presented enabled the CET program to implement continuous improvement measures into the program, and thus, could be implemented by other construction engineering programs nationwide, both as a general assessment tool and/or to achieve ABET accreditation.

Introduction

With today's competitive educational environment, assessment has become one of the main drivers of excellence for most educational institutions [1], giving educational institutions a measure to report to policy makers and the public [2]. This culture of accountability and assessment plays a significant role in the advancement of educational programs, and engineering programs are no different. In addition, industry, state legislatures, and accreditation entities has placed great pressure on academic institutions to develop a structured, systematic, and effective assessment process into all its programs. The Accreditation Board for Engineering and Technology (ABET) is one of these agencies that included program outcomes and assessment as its key criterion [2]. Based on the ABET criteria, the institution's assessment effort should focus on measuring student learning outcomes (SOs) in a systematic and effective manner that allows for continuous improvement [1, 2].

In addition to being an accreditation requirement for engineering programs, assessment efforts help educators plan forward their education process with robust sound methods and data, rather than arbitrary methods based on trials and errors. The challenge of any program assessment process has always been the development of a structured, systematic, and effective process that encompasses all stakeholders, and provides opportunity for continuous improvement, as poorly constructed assessments can lead to loss of time, money, and educators' energy [3]. Systematic assessments, though challenging, are necessary for program improvement [2, 4]. With the move of California State Polytechnic University, Pomona's (CPP) Construction Engineering Technology (CET) program to the Civil Engineering Department, and mandated changes in course units by the State University system, it was necessary for the program to develop a robust assessment framework to assess and ensure its achievement of the major department's educational philosophy, vision, and mission. This entailed providing a broad-based practice-oriented curriculum that prepares students for immediate entry into engineering practice, or for graduate studies. This paper, thus, presents the assessment framework developed, adopted, and implemented by the CET program at CPP. It will describe the steps that the institution has taken to develop the assessment and continuous improvement processes into the educational environment, as well as demonstrate how the framework works. The paper starts with a general literature review section, followed by the framework development and implementation, concluding with the major findings and conclusions.

Literature Review

'Assessment', as a term is used to define "the act of collecting data or evidence that can be used to answer classroom, curricular, or research questions" [3]. Assessment methods, on the other hand, are the actual procedures used to support the process of collecting data, and thus should be thoughtfully designed [3]. As cited by researchers, other than accreditation requirements, there are many reasons of enforcing a robust assessment process within any educational program, such as the effectiveness of the design, delivery, and direction of an educational program, characterizing what a student knows, informally understanding student-learning progress and how it affects expertise in a subject, and identifying strategies for improving student learning [1, 2, 4]. As McGourty et al. [1] states it, an effective assessment processes need to answer the following question: *"Have the program's graduates acquired the knowledge and skills defined by predetermined educational objectives and outcomes?"* For any assessment process to be effective, it should -as a start - align with the entire institution's vision, mission, and goals, and - as an ongoing process- allow for the results to be applied towards continuous improvement of the learning outcomes, as well as the entire program effectiveness [1]. There are many lines of research in assessment in engineering education. These include, but are not limited to, research that presented general assessment tools at various levels, evaluated the validity and reliability of assessment tools [4, 5], proposed specific institutional framework in various engineering disciplines [1], or focused on specific learning outcomes [2].

In terms of assessment levels, assessment could be implemented at various levels, depending on the objective of its implementation. For example, at course level, it is more of a function of understanding what students are learning and assigning them a letter grade, while on a program level, it might be geared towards an understanding of students' knowledge of an overarching topic in a certain domain. There are many methods/tools of assessment whether on the course or the program level. The challenge is usually to identify the appropriate assessment tool in designing an assessment approach [4]. This is because of the diversity of tools available and what counts as evidence of learning. For example, Turns et al. [4] demonstrated the use of concept maps to explore both course-level and program-level assessment issues. Davis et al. [2] focused on specific aspects of the student learning objectives, such as improvement and evaluation of 'design' education, in alignment with ABET's design learning outcome definition. Validity and reliability of tools proposed was discussed by Moskal et al. [5] as two key measurement concepts that should be used to improve assessment efforts in engineering education. An understanding of these two concepts could better equip educators in implementing rigorous assessment standards that should be systematic [5].

In terms of specifically geared papers on institutional assessment processes, many engineering programs applied ABET assessment frameworks for their programs which efficiently improved their program qualities, such as student outcomes and performances. McGourty et al. [1] provided an overview of New Jersey Institute of Technology (NJIT) institution's efforts in establishing a comprehensive assessment program for continuous improvement, aligned with ABET Engineering Criteria 2000. Damaj et al. [6] created a unified framework that enables the evaluation and assessment for student outcomes to be efficiently improved. The proposed framework unified both assessment and evaluation of SO attainment and evaluation of students' performance. Assessing SOs in evaluating student performance were used as program measurements. The performance indicators (PIs) were also used to define the scope of the SOs and enables more targeted mapping of the assessment and evaluation elements to the SOs. The key point of this ABET framework was driven by importance of the unification of SO attainment and students' performance, which is a unique application method. Surveying tools, like exit surveys, was the measurement of assessment, but the focus in the proposed methodologies was the student attainment in course level, which used the course learning outcomes (CLOs). Using a qualitative rubric, assessment and evaluation components (AECs), like exam, quiz, homework, project components, is the way of measuring the attainment of every CLO per student. The achievement percentage in a course presents the assessment scores per CLOs. Figure 1 below describes the hierarchy of the framework proposed by Damaj et al. [6]. A hierarchal framework enables vertical assessments of SOs and horizontal evaluation of student performances in courses. This unified framework led to successful identification of improvement aspects in the Computer Engineering program [6].

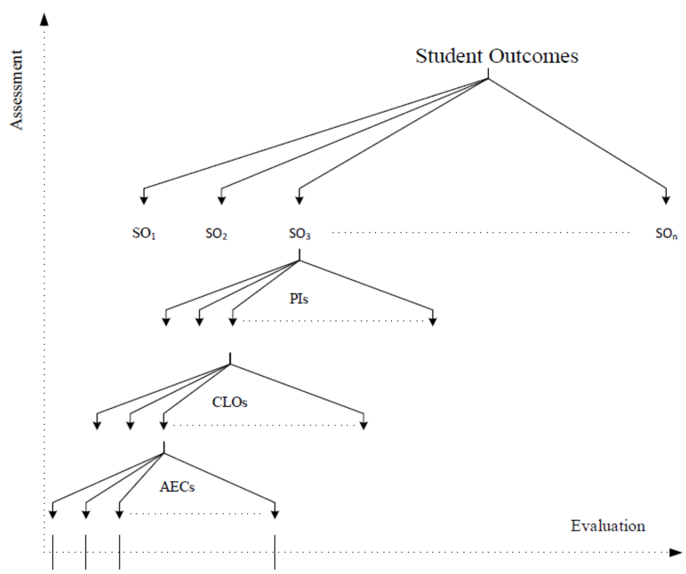


Figure 1: Hierarchy of the unified framework for assessment and evaluation [6]

Christensen et al. [7] presented the successful example of unifying assessment activities in Electrical Engineering Department in University of South Florida. They specifically developed the evaluation of web-based accreditation portal to the engineering college. The research proved the need of a web-based accreditation tool. By setting and utilizing a website portal system, it was expected that all faculty and ABET evaluators' experience with ABET accreditation would be simplified. The paper also showed how this system helped simplify and organize the assessment process, and store massive assessment data efficiently. The paper again recommended the need for a systematic protocol for ABET system. Based on the literature review presented and the need of CPP's CET program to develop a systematic efficient assessment, this paper presents the assessment framework developed, adopted, and implemented by the CET program at CPP, encompassing a demonstration of the actual framework implementation and the continuous improvement processes entailed.

Methodology- Framework Development

The framework is set up to measure the attainment of both the PEOs and SOs, as required by the ABET **Error! Reference source not found.** shows a schematic diagram of the process that the construction faculty uses each cycle. It was necessary to involve all the stakeholders, including students, faculty, alumni, and industry throughout the entire process. The assessment of the PEOs was conducted through indirect measures, including surveys to alumni and industry advisory council (IAC). The assessment of SOs was conducted on a six-year cycle, in which both **direct and indirect** measures were used by the CET program. Direct measures included PIs that are drawn from both the senior project and the coursework. Indirect measures include senior exit surveys, alumni surveys, and IAC surveys. These tools will be discussed in further details in Sections A and B, covering the assessment tools used for the PEOs, and then moving into detailing the assessment measures for the SOs.

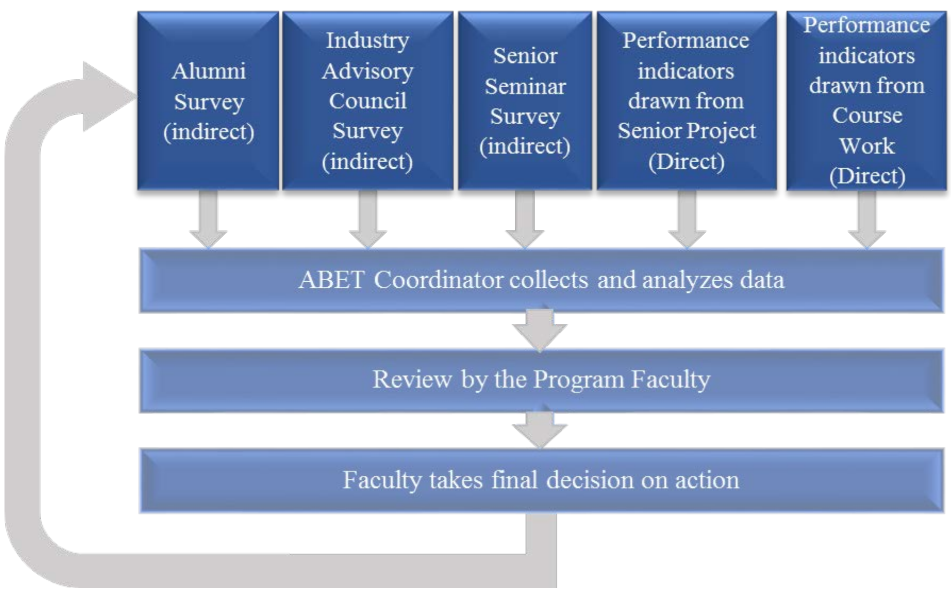


Figure 2: Assessment Process and Assessment Cycle

A. Assessment of Program Educational Objectives (PEOs)

PEOs are broad statements that describe what graduates are expected to attain within a few years of graduation, generally within 3 to 5 years window after graduation. The evaluation and assessment of the work done by the recent alumni and their employers are performed by means of indirect measurement tools, as they are considered more feasible than direct measurements. These indirect measures included surveys to alumni and IAC members. The surveys are considered indirect measures because they ask respondents for their opinions on how well a graduate has achieved each objective. An online survey was developed and administered in the 2016-2017 academic year. The survey was developed to assess graduates' ability to achieve the following four PEOs using a 5-point Likert scale of achievement, with 1 being very good, to 5 being very poor:

PEO 1: Pursue engineering and management careers in the civil engineering industry and related fields.

PEO 2: Maintain competency via continuing education and graduate studies.
PEO 3: Work with paramount consideration for the safety, health, and welfare of the public, obtain professional licensure, and actively participate in professional societies.
PEO 4: Practice locally, regionally, or internationally, integrating the broader political, economic, legal, environmental, and societal impacts of projects in their decisions.

B. Assessment of Student Outcomes (SOs)

The assessment of SOs is conducted on a six-year cycle, in which both **direct and indirect** measures are used by the CET program.

Indirect Measures. In case of the indirect measures (perception), the senior exit survey includes 11 questions relating to each student outcome (shown in Table 2). For example, for outcome (a) and (g), the graduating senior students are asked to rate the following questions, based on a 5-point Likert scale from 100% being ‘extremely effective’ to 0% being ‘not at all effective’:

Outcome (a): How effective is the curriculum & the teaching environment in developing your ability to use the techniques, skills, and modern technical tools necessary for construction engineering technology practice?

Outcome (g): How effective is the curriculum & the teaching environment in developing your ability to communicate effectively, both orally and in writing?

Direct Measures. The direct measures for the SOs involved three main steps: (1) development of curricular mapping to the SOs, (2) development of the PIs, and (3) selection of sample courses on which to use the PIs. For step 1, each outcome is mapped to the CET courses in a matrix to make decisions about where the summative data would be collected for each outcome. A sample of the matrix developed in shown in Table 1, showing also the level of attainment expected in each class which is divided based on a spectrum that starts from Introduce (I), moves to Develop (D), and then finally to Master (M). The matrix as well as the coverage level was a product of discussions by the Assessment Department Committee members and the CET program faculty.

Table 1. Snapshot of the Curricular Map of CET with SOs

Course	**Student Outcomes**										
	a	**b**	**c**	**d**	**e**	**f**	**g**	**h**	**i**	**j**	**k**
	Coverage Level:			**I – Introduce**			**D - Develop**			**M - Master**	
Program Core Courses											
ETC 130/130L	I		I								
ETC 131/L or CE 134/L	I, D	D	I	D	D	I	D				I,D
ETC 132/132L	I						I				
ETC 204					I			I	I		I
ETT 210	I,D				D						
ETC316		D		D		D					
ETC317		D		D		D					
ETC401	M						M	M	M		M
ETC403							M	M	M	M	

For step 2, literature was reviewed for any existing indicators for a through k criteria for an Engineering Technology Accreditation (ETAC) program. The criteria reviewed were then developed further to accommodate CPP’s CET program. Table 2 shows the PIs criteria developed for each SO. In step 3, each SO was mapped into a minimum of one course, for which a method of assessment was chosen. The assessment method could be a class project report, assignment, or student presentations, depending on the SO being assessed. Table 3 shows SO *(a)* including the PI, the courses that could have been used based on the mapping table, the method of assessment which in this case included the project, the specific course which was selected to obtain the data, years the data points were collected, and finally the target performance.

Table 2. Performance Indicators of Student Outcomes (a) through (k)

Student Outcome (SO)	**Performance Indicator (PI)**
a. An ability to select and apply the knowledge, techniques, skills, and modern tools of the discipline to broadly-defined engineering technology activities;	1. Identifies appropriate tools for a given task. 2. Applies appropriate tools/resources for a given task 3. Uses lab equipment and resources appropriately.
b. An ability to select and apply a knowledge of mathematics, science, engineering, and technology to engineering technology problems that require the application of principles and applied procedures or methodologies;	1. Selects appropriate theory, model, or governing equation. 2. Uses simplifying assumptions or limitations of the chosen model. 3. Implements theory, model, or governing equation correctly to perform analysis
c. An ability to conduct standard tests and measurements; to conduct, analyze, and interpret experiments; and to apply experimental results to improve processes;	1. Explains theory, procedure, and standard testing methods used in the experiments. 2. Analyzes and interprets results of experiments including, where applicable, comparison of results to theory, and error analysis. 3. Presents the result in a professional manner
d. An ability to design systems, components, or processes for broadly-defined engineering technology problems appropriate to program educational objectives;	1. Identifies specific project objectives, standards, and constraints based on general project requirements 2. Generates and analyzes alternative solutions 3. Synthesizes all data and chooses the optimal solution based on evaluation of project criteria
e. An ability to function effectively as a member or leader on a technical team;	1. Effectively uses time 2. Participates in team work 3. Makes appropriate decisions based on given constraints 4. Demonstrates accountability in a team setting
f. An ability to identify, analyze, and solve broadly-defined engineering technology problems;	1. Prepares a model 2. Applies Mathematical Analysis 3. Presents final results
g. An ability to apply written, oral, and graphical communication in both technical and non-technical environments; and an ability to identify and use appropriate technical literature;	1. Communicates information in a logical, well-organized manner 2. Uses graphics effectively to illustrate concepts 3. Addresses questions in a well-structured soundly justified responses
h. An understanding of the need for and an ability to engage in self-directed continuing professional development;	1. Demonstrates a developing sense of self as a learner, building on prior experiences to respond to new and challenging contexts. 2. Selects and uses information to investigate a point of view or conclusion, and evaluates it critically
i. An understanding of and a commitment to address professional and ethical responsibilities including a respect for diversity;	1. Recognition of dilemma 2. Application of appropriate code of ethics"
j. A knowledge of the impact of engineering technology solutions in a societal and global context;	1. Demonstrates importance of diversity 2. Demonstrates responsibility of the engineer 3. Recognizes cultural impact of the solutions
k. A commitment to quality, timeliness, and continuous improvement.	1. Discusses and analyzes contemporary issues 2. Demonstrates depth of knowledge of a major issues

Table 3. Student Outcome *(a)* Assessment Process

Performance Indicators	**Educational Strategies**	**Method(s) of Assessment**	**Where data are collected**	**Length of assessment cycle**	**Year(s) of data collection cycle**	**Target Perfo-rmance**
1. Identifies appropriate tools for a given task.	ETC 130/130L ETC 131/L or CE 134/L ETC 132/132L ETC 140L ETC250/250L ETC270 ETC279/279L ETC304 ETC305 ETC312 ETC401 ETC405 ETC411/411L ETC420 ETC431/431L ETC461 ETC462	Faculty assessment of a topographic mapping surveying project	ETC 134/134L	Every other 1-2 year(s)	2013, 2014, 2016	75%
		Senior Exit Survey - Question on outcome “a” achievement	ETC 461 and ETC 462	Every other 1-2 year(s)	2012, 2016, 2017	
2. Applies appropriate tools/resources for a given task		Faculty assessment of a topographic mapping surveying project	ETC 134/134L	Every other 1-2 year(s)	2013, 2014, 2016	
		Senior Exit Survey - Question on outcome “a” achievement	ETC 461 and ETC 462	Every other 1-2 year(s)	2012, 2016, 2017	
3. Uses lab equipment and resources appropriately.		Faculty assessment of a topographic mapping surveying project	ETC 134/134L	Every other 1-2 year(s)	2013, 2014, 2016	
		Senior Exit Survey – Perception question on outcome “a” achievement	ETC 461 and ETC 462	Every other 1-2 year(s)	2012, 2016, 2017	

Results & Analysis- Framework Implementation

A. Program Educational Objectives (PEOs)

The alumni and employer ratings were combined into a composite rating for each PEO. This composite rating was then compared to the goal that was set at a score of 2 (good). This goal was originally established by consensus of all faculty members in the program. The majority of the respondents had graduated in the last 10 years. The positions of the survey respondents range from project managers to field engineers. As shown in Figure 3, all PEOs met the goal. Part of the assessment process was also to make sure proper documentation is done for the tools, as well as the results and analysis of the data collected. This not only helps document the assessment process but also provides for organizing and maintaining the data over many assessment cycles. Thus, the program would adopt a system where surveys, data generated, and analysis conducted would be stored on the program’s shared folder in each cycle.

B. Student Outcomes (SOs)

Since the purpose of the paper is to present the assessment framework utilized as one that could be adopted by other Construction Engineering Programs, the authors will demonstrate the framework implementation using outcomes *(a) An ability to select and apply the knowledge, techniques, skills, and modern tools of the discipline to broadly-defined engineering technology activities and outcome;* and outcome *(g) An ability to apply written, oral, and graphical communication in both technical and non-technical environments; and an ability to identify and* *use appropriate technical literature*, rather than going through all the assessment results. Results of the two sample student outcomes are reported in

Figure 4 (a) and (b). Each of the SO figures represents the activity for the ABET accreditation cycle. Each figure also includes both the direct tools such as PIs for the courses that provide students an opportunity to demonstrate the indicator, and the indirect tool used such as the senior exit surveys, alumni surveys, and IAC surveys.

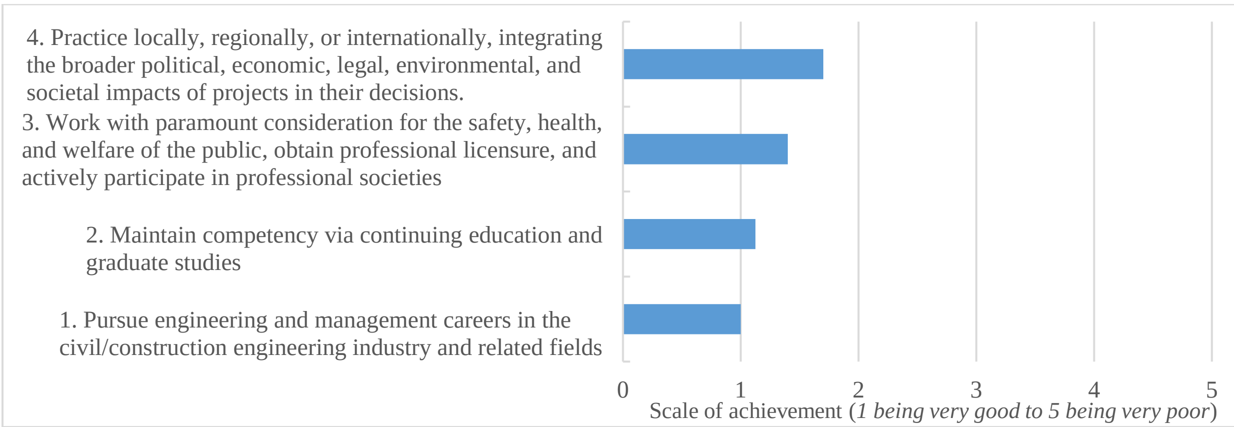
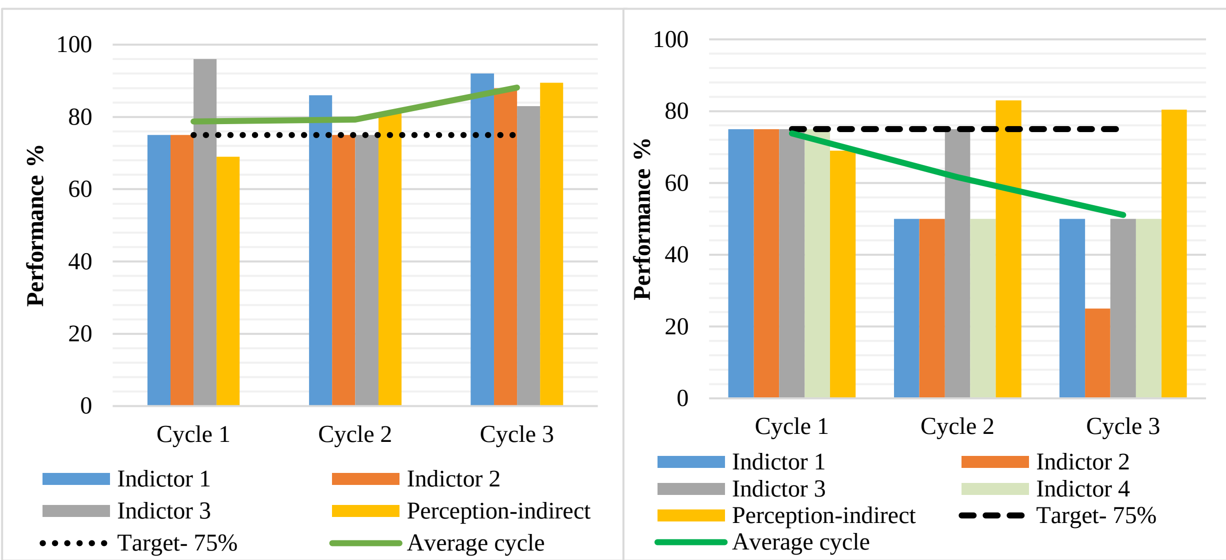


Figure 3: Alumni and Employer's PEOs Evaluation (Indirect)



(a) Student Outcome "a" *(b) Student Outcome "g"*

Figure 4: Trend for Student Outcomes "a" and "g"

Outcome (a).

Figure 4a shows the results of the assessment process for outcome *(a)*. The x-axis shows the three cycles each corresponding to the cycle of data collection. The y-axis shows the performance percentage. For direct measure, this percentage was calculated based on the rubrics (PIs 1 through 3) used to assess the data (lab report) collected for outcome *(a)*. The following paragraphs detail outcome *(a)* assessment results, and the evaluation and actions taken in each cycle, as a respective sample. Summative data for the three indicators were collected in the surveying course topographic mapping project, as a direct measure. In this course, students are given a project, which requires them to collect data in the form of topographical surveying using total station and prism rod. A rubric, including the PIs, listed in Table 2, was used by the faculty to assess the achievement of the students in the lab report.

Cycle 1- Assessment Results & Evaluation Actions. All indicators shown in Figure 4a met the target performance of 75%. A more detailed look at the results, however, showed that in the first cycle, the percent of students that demonstrated each criterion were as follows: Indicator #1-75%; Indicator #2-75%; and Indicator #3-96%. As for the indirect measures, the student survey responses, as pertains to outcome *(a)*, reported 73%, which did not meet the target. Although all the direct indicator measures met the 75% target performance level in the first cycle, the indirect student perception measure did not meet the target performance percentage. Faculty noticed that the survey equipment used was dated and students had difficulty programming and using them. Students and alumni, also, expressed concern that these equipment devices are not what are commonly used in practice and questioned the value of learning the techniques of dated equipment. As a continuous improvement strategy, the department wrote several grants to acquire modern surveying tools (total station) compatible with what is used in industry, which were secured.

Cycle 2- Assessment Results & Evaluation Actions. The second cycle showed mixed results, with improvement in indicators #1 (increased by 11%), while indicator #2 remained the same (75%), and finally indicator #3 decreased by 21% (75%). The student survey responses, as pertains to outcome *(a),* reported an improvement from last cycle and met the target at 81%. With the improvement in the lab equipment and the new equipment being more user friendly, students received better training on techniques that they will use on the job site, and reported better ratings in the survey. Students recognized the relevance of materials being taught, and appreciated how it prepared them for their future career.

Cycle 3- Assessment Results & Evaluation Actions. The third and final cycle showed improvement in all three indicators. As for the indirect measures, the student survey responses, as pertains to outcome (a), showed improvement as well. At this point, faculty members were quite satisfied with the improvements observed, and how the indicator met the target performance. The plan was to continue to monitor the outcome in the next assessment cycles.

Outcome (g).

Figure 4b shows the results of the assessment process for outcome *(g),* with x-axis showing the three assessment cycles, and y-axis the performance percentage. For direct measure, this percentage was calculated based on the rubrics (PIs 1 through 4) used to assess the data (project report) collected for outcome *(g).* The following paragraphs detail outcome *(g)* assessment results, and the evaluation and actions taken in each cycle, as a second respective sample. Summative data for the four indicators were collected in the Estimating I course (ETC 304), as a direct measure. In this course, students are given a project that requires them to develop a project report that incorporates an estimate of a construction building. A rubric, including the PIs listed in Table 2, was used by the faculty to assess the achievement of the students in the project report.

Cycle 1- Assessment Results & Evaluation Actions. In the first cycle, all direct indicators met the target performance of 75%. As for the indirect measure demonstrated by the student survey response, it did not meet the target (69%).The indirect measure reflected the concerns that were received from students regarding the lack of training they received in estimating software. Through their internship experience, they realized most construction firms utilize construction software in their daily operations. The use of hand calculation, which is the main method of estimating in class is hardly used in the industry. Accordingly, faculty made effort to acquire estimating software such as Bluebeam and On Screen Takeoff

Cycle 2- Assessment Results & Evaluation Actions. The second cycle showed a drop in the performance percentage in indicators #1, #2, and #4 (from 75% to 50%), with indicator #3 sustaining the 75% target. The indirect measure showed improvement (83%). With the drop observed in PIs, especially as pertains to communication, faculty decided to encourage students to take the technical communications course, as an elective. This course is geared towards improving student's communication skills, in general.

Cycle 3- Assessment Results & Evaluation Actions. In the third cycle, the PIs were still not meeting the performance target (indicator 1 – 50%, indicator#2- 25%, indicator 3- 50%, indicator 4- 50%). Indirect indicators, however, did meet the target performance at 80%. The average performance was still not meeting the target and more efforts were made to improve student attainment of this indicator. This includes construction faculty getting training on different software to familiarize themselves with the software. In addition, the faculty member teaching this course is proposing to split the course to include a 1-unit lab, in which software training would be conducted in this lab. Faculty will monitor attainment of these indicators after the implementation of these strategies and report the progress made in the next cycle.

Conclusions

Although collecting data in an educational environment could be considered an easy thing to accomplish, applying the results is quite another thing. This paper proposes an assessment framework developed, adopted, and implemented by the CET program at CPP. The framework is set up to measure the attainment of both the PEOs and SOs, as required by ABET using both direct and indirect measures. Direct measures included the development of PIs to measure the attainment of the SOs using both the senior project and the course work. Indirect measures included assessment of both PEOs and SOs using senior exit surveys, alumni surveys, and IAC surveys. The model was presented and demonstrated by its implementation on the PEOs, as well as on two of the SOs during the last program ABET cycle. The team found it critical to identify how the data would be reported and applied early on in the design process. The framework enabled the CET program to implement continuous improvement measures into the program, and thus, could be implemented by other programs nationwide, as both a general assessment tool and to achieve ABET accreditation.

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